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Reduction of the Radius of Probability Circle in Typhoon Track Forecast

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Abstract

RSMC Tokyo - Typhoon Center of the Japan Meteorological Agency (JMA) presents tropical cyclone track forecasts with probability circles* to indicate uncertainty of the forecasts. Based on the verifications of the forecasts issued from 2001 to 2003, the Typhoon Center reduced the radii of probability circles by 10% on average on 1 June 2004.

* A circular range in which a tropical cyclone is located with a probability of 70% at each forecast time.

1. Introduction

In consideration of the significant impact of tropical cyclone (TC) track forecasts upon disaster prevention activities as well as unavoidable error in the forecasts, most of the National Meteorological Services represent track forecast with a range of possible deviation. RSMC Tokyo - Typhoon Center (hereafter referred as Typhoon Center) adopts "probability circle" for track forecast, a circular range in which TC is located with a probability of 70% at each forecast time. Radius of probability circle is determined statistically so that the 70% of the forecasted positions will fall into the circle as shown in Fig.1. Radii of the probability circles are decreased as positional errors of forecast are decreased with technical improvements.

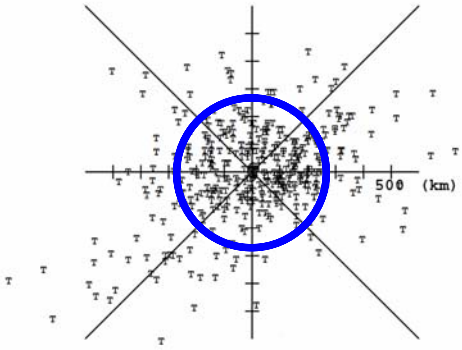

Fig.1 The forecasted positions (indicated by "T") relative to the analyzed positions (center of the figure), and a circle into which the 70% of the TCs moved.

On 1 June 2004, the Typhoon Center reduced the size of the probability circles in TC track forecasts. Fig.2 shows a comparison of the new probability circles with old ones. Please note that as shown in the map, centers of the probability circles and lines connecting the centers are intentionally not depicted to avoid biased attention of uses on the centers of the circles.

2. Verification of Probability Circle

The radii of probability circles are calculated from the statistical relationship between forecast errors and TC movements such as moving speeds and directions at the forecast time for the past several years. The period for the statistics is determined in consideration of fair sampling of forecasts as well as consistency of main properties of the numerical weather prediction (NWP) model used for typhoon forecasting.

Radii of the probability circles being adopted by Typhoon Center until the revision in June 2004 were derived from the statistics for the four years from 1996 to 1999. Table 1 shows the radius of probability circle (nm) used until May 2004 in the upper row in each cell. The radius depends on the forecasted moving speed and direction as well as the forecast time. The moving speeds are divided into 6 ranges (less than 5, 5-10, 10-15, 15-20, 20-30, and more than 30 knots), and the TC movements are classified into three modes ("before recurvature", "during recurvature" and "after recurvature") depending on the forecasted moving directions.

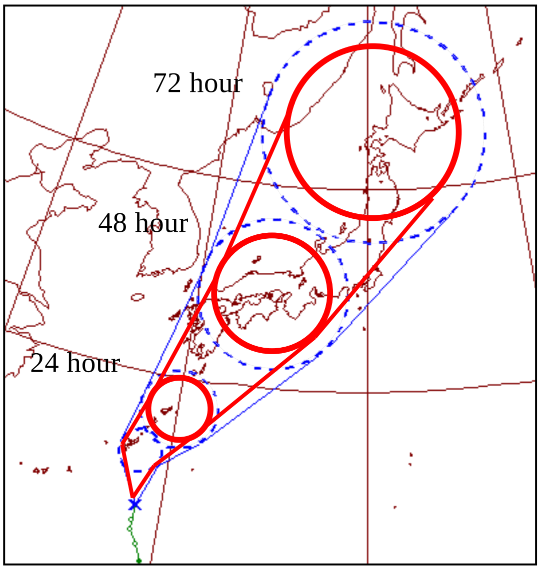

Fig.2 Comparison of the new probability circles with the old ones in the case of a track forecast of TY ETAU (T0310) issued at 12UTC 6 August 2003. The inner solid circles and outer dashed circles indicate new and old probability circles, respectively.

Fig.3 shows the ratios of TCs that actually fell inside the probability circles (hitting ratios) to all TCs from 2000 to 2003. The increase in hitting ratio shown in the figure indicates some improvement in NWP model performances in the prediction of TC tracks during the period. The trend is accordingly presented in the year-year changes of the position errors in Fig.4.

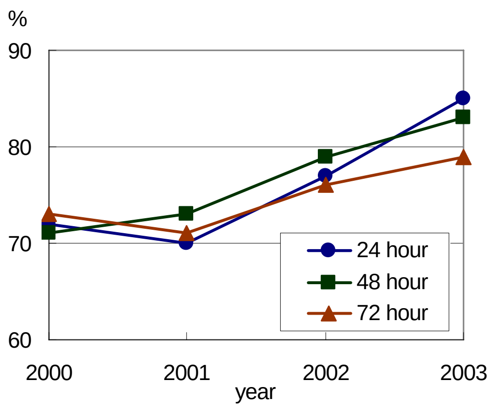

Fig.3 Ratios that a tropical cyclone actually moved into the issued probability circle (hitting ratios) of 24, 48, and 72 hour forecasts from 2000 to 2003. Vertical axis is the ratio, and horizontal axis is year.

Histograms of position errors of all the forecasts from 2001 to 2003 are shown in Fig.5, in which cumulative ratio (the ratio of the accumulated number of forecasts with errors less than certain distance to the total number of the forecasts) is also presented. The position error of 24 hour forecast corresponding to the cumulative ratio of 70% - 170km (90nm) as compared to the radius of the probability circle for all the cases shown in Table 1 - 100nm suggests the significance of revision of the radius size and accordingly formed a basis to prepare a new table in June 2004.

Fig.5 also shows that the TCs that fell within 15km from the center of the probability circle are less than those that located between 15km and 30km in 24 hour forecast. However, this does not mean a tendency of TCs to deviate from the center of the probability circle. The probability density is calculated and shown in the Appendix 1. Several outliers found in the histogram are worth investigating. The results are described in the Appendix 2.

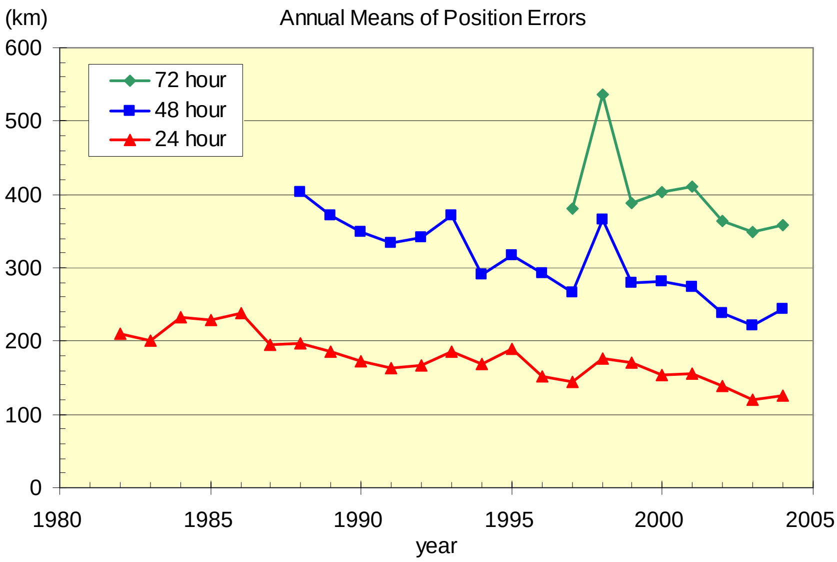

Fig.4 Annual means of position errors of 24, 48 and 72 hour forecasts from 1982 to 2004.

3. Estimation of the radius

Table 1 presents the distance (nm) corresponding to cumulative ratio of 70% during 2001 through 2003 in the middle row of each ell in bold, which is an estimated radius for a new table. The number of samples is also listed in the lower row in each cell. It is found that there are some irregularities in the table. For example, tendency of radii for 72 hour forecast after recurvature according to moving speed is different between in the previous table (upper row) and in the new table. The previous radius for 5-10 knots, 260nm, is the least, while the estimated radius for 0-5 knots, 240 nm, is the least. Furthermore, the error of 24 hour forecast with the moving speed less than 15 knots seems to depend on the moving direction, rather than on the moving speed, although 24 hour forecast is not classified with moving direction in the previous table.

Considering the feature mentioned above, we decide that the cases with moving speed less than 15 knots is divided only by the moving directions but not moving speed including 24 hour forecast. As the difference between estimated radii of 15-20 knots and those of

20-30 knots is small, they are unified to one class for 15-30 knots. There is no class considering the moving direction for the moving speed more than 15 knots. Then the class of moving speed, six, is reduced to three (0-15, 15-30, 30- knots). Since the number of sample is small for the moving speed more than 30 knots, the reducing rate of 15-30 knots from the previous table to the new table is applied for the radii more than 30 knots.

The new table is shown in Table 2, which has been used operationally since June 2004. Mean hitting ratios of probability circles in 2004 were 74, 67 and 70% for 24, 48 and 72 hour forecasts, respectively, after the new table of radius of probability circle was applied. The new table can correctly represent the 70% probability. Mean radii of probability circles of issued forecasts in 2004 after using the new table and those in 2003 are listed in Table 3. The table shows that the radii of probability circle are decreased by nearly 15%. The new probability circle assists in more effective disaster prevention activities including the preparedness against TCs with more focus on the target area than before.

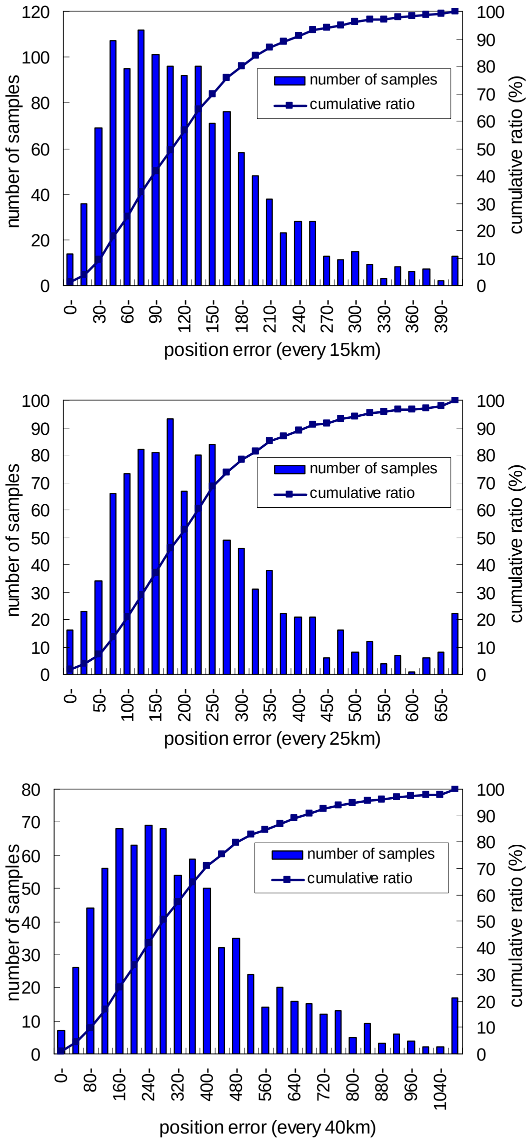

Fig.5 Histogram (bars) and cumulative ratio of position error (polygonal lines) from 2001 to 2003. 24hour forecast (top), 48 hour forecast (middle) and 72 hours forecast (bottom). Histogram is measured with left axis and cumulative ratio is measured with right axis.

4. Concluding remarks

The radius of the probability circle was reduced in 2004 based on the statistics from 2001 to 2003. The position errors in 2002 are evidently reduced compared with those in 2001 as shown in Fig.4. The major reason can be attributed to the introduction of the three dimensional data variational method to the global data assimilation of NWP system in autumn 2001. As is shown in the Appendix 2, the most of the outliers are in 2001. Therefore, if the statistics from 2002 to 2004 is used, the radius can be reduced a little bit.

Recent verification shows that the position errors of Tropical Storm (TS) and Strong Tropical Storm (STS) are larger than those of Typhoon (TY). The classification depending on the strength of TC may bring more proper representation of uncertainty.

The present radius is determined statistically. However, the dynamical method can be applied after the Typhoon Ensemble Prediction System (EPS) starts in 2007. The preliminary verification on the TC track forecast using the results of the EPS for medium range forecast shows that position error and spread of forecast have a correlation. The radius of the probability circle can be determined based on the spread derived from EPS in future.

Table 3. Mean radius of probability circle (km) in 2004 after the new radius of probability circle was applied and that in 2003.

year \ Forecast hour	24	48	72
2003	189	332	502
2004	160	281	420

Table 2 Radius of probability circle (nm) used since June 2004. 24 hour forecast (top), 48 hour forecast (middle) and 72 hour forecast (bottom). Hatched area means the number of sample is smaller than 20.

24 hour forecast

moving direction \ moving speed	≦ 15kt	15 < V ≦ 30kt	30kt < V	all moving speed
180-320°	80			*80*
320-10°	90			*90*
10-180°	100			*100*
all direction		100	150	*90*

48 hour forecast

moving direction \ moving speed	≦ 15kt	15 < V ≦ 30kt	30kt < V	all moving speed
180-320°	150			*140*
320-10°	150			*150*
10-180°	160			*170*
all direction		170	190	*150*

72 hour forecast

moving direction \ moving speed	≦ 15kt	15 < V ≦ 30kt	30kt < V	all moving speed
180-320°	220			*220*
320-10°	220			*220*
10-180°	290			*290*
all direction		270	400	*230*

Appendix 1 Probability Density of the Forecasted Position of TC Center

Forecast error of the center position has the normal distribution. Fig.A1 shows the histogram of the probability density calculated from the same data used for Fig.5. The probability density is defined as the number of the samples in a certain area divided by the area normalized by the area of the 70% probability circle as well as by the total number. Fig.A1 shows that the probability density is generally higher in the inner area. The probability density function assuming the normal distribution of the forecast error of the TC position, shown in Fig.A1, agrees well with the probability density calculated from actual distribution.

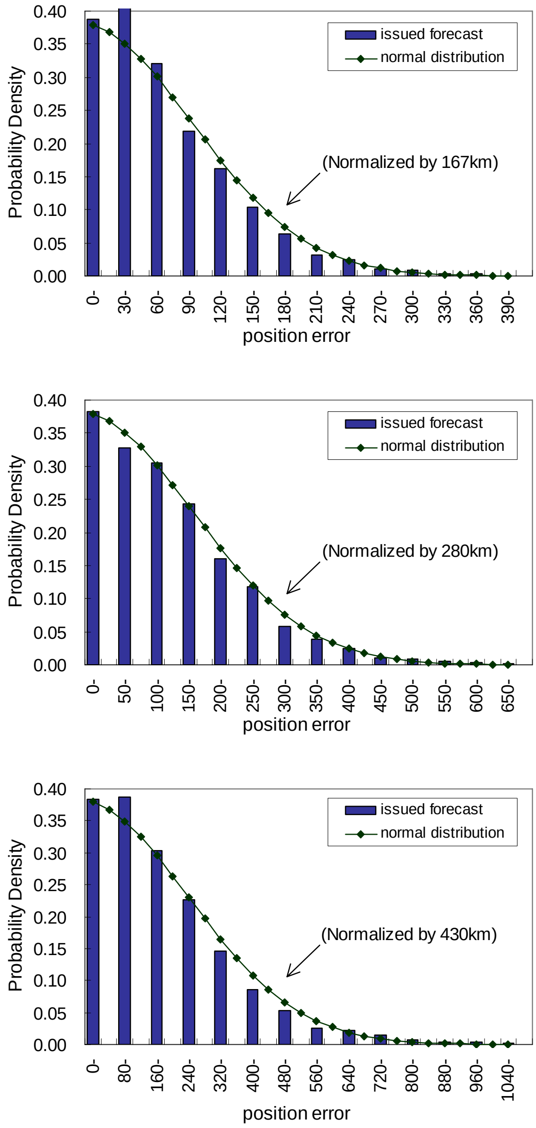

Fig.A1 Probability density of the actual track forecast error from 2001 to 2003 (bars) and probability density function assuming the normal distribution (polygonal lines). 24hour forecast (top), 48 hour forecast (middle) and 72 hours forecast (bottom).

Appendix 2 Forecast with Relatively Large Error

There are several cases with relatively large error, which are listed in Table A1. The cases with position error of more than 675km and 1080km for 48 hour forecast and 72 hour forecast, respectively, are listed in the table. 26 cases of 10 named tropical cyclones are found. The forecasted moving direction of the most of the cases is north-westward. The features of these cases can be summarized as follows:

(a) TC was forecasted to start to recurve, although it recurved and accelerated (Fig.A2). The cases where acceleration is not adequately forecasted despite of the almost correct track (Fig.A3) are included. (8 TCs, 19 cases)

(b) TC was forecasted to move northward in the very early stage, although it moved westward (Fig.A4). (1 TC, 6 cases)

(c) TC was forecasted to be almost stationary just after it became TS in the South China Sea, although it moved north-eastward (Fig.A5). (1 TC, 1 case)

65% of the cases listed in Table A1 occurred in 2001. It suggests that the recent improvement of NWP system such as data assimilation method, physical parameterization schemes and bogussing technique reduced the large error. It is, however, still difficult to forecast TC track in a very early stage as well as acceleration after the recurvature in 2004.

Table A1 List of the 48 and 72 hour forecasts with relatively large error from 2001 to 2003.

	Forecast time				Forecast	Error	moving direction	moving speed
	Year	Month	Day	UTC	Hour	(km)	(degree)	(knots)
T0106 KONG-REY	2001	7	25	12	72	1094	20	5
		7	25	18	72	1160	40	5
		7	26	12	48	765	40	6
T0111 PABUK	2001	8	14	12	48	1054	10	9
		8	14	12	72	1469	360	13
		8	14	18	48	884	10	10
		8	14	18	72	1458	360	15
		8	15	00	48	961	10	14
		8	15	00	72	1544	10	16
T0120 KROSA	2001	10	05	18	72	1214	360	3
		10	06	00	72	1448	10	3
		10	07	00	48	697	30	11
T0121 HAIYAN	2001	10	15	00	72	1456	0	0
		10	15	18	48	691	60	7
		10	16	00	48	848	50	9
T0125 FAXAI	2001	12	22	18	72	1162	30	13
		12	23	12	48	681	20	12
T0203 HAGIBIS	2002	5	18	00	72	1153	30	15
T0221 HIGOS	2002	9	28	18	72	1097	20	20
		9	29	00	72	1105	20	20
T0225 HAISHEN	2002	11	22	06	48	800	40	7
		11	22	12	48	774	40	11
		11	22	18	48	772	40	14
T0304 LINFA	2003	5	26	00	72	1092	0	0
T0315 CHOI-WAN	2003	9	18	00	72	1278	330	3
		9	18	12	72	1096	40	5

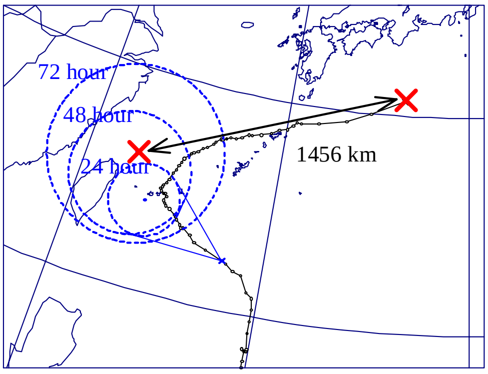

Fig.A2 Track of T0121 HAYAN with forecast at 00UTC 15 Oct. 2001. Probability circles indicate forecast, and solid line indicates analyzed typhoon track. TC was forecasted to start to recurve, although it recurved and accelerated.

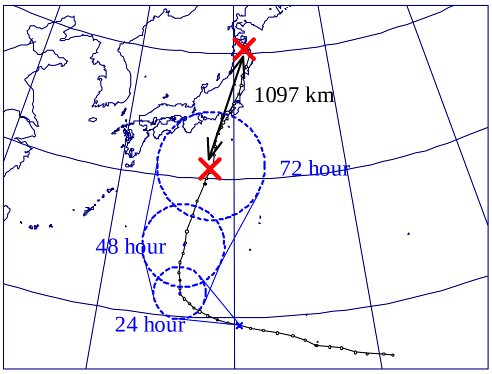

Fig.A3 Track of T0221 HIGOS with forecast at 18UTC 28 Sep. 2002. Acceleration is not adequately forecasted, although the forecasted track is almost the same as the actual one.

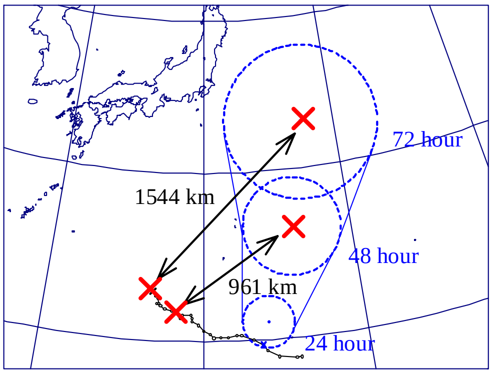

Fig.A4 Track of T0111 PABUK with forecast at 00UTC 15 Aug. 2001. TC was forecasted to move northward in the very early stage, although it moved westward.

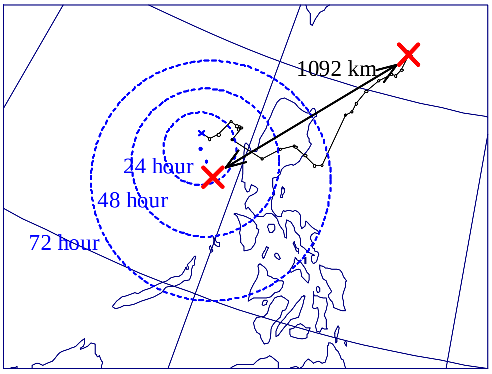

Fig.A5 Track of T0304 LINFA with forecast at 00UTC 26 May 2003. TC was forecasted to be almost stationary just after it became TS in the South China Sea, although it moved north-eastward.

Table 1 Radius of probability circle (nm) used until May 2004 (upper row in each cell), distance (nm) corresponding to cumulative ratio of 70% (middle row in bold in each cell) and number of samples in 2001-2003 (lower row in italic in each cell). 24 hour forecast (top), 48 hour forecast (middle) and 72 hour forecast (bottom). Angle of the moving direction is measured clockwise from north. Moving directions of 180°-320°, 320°-10° and 10°-180° correspond to “before recurvature”, “during recurvature” and “after recurvature”, respectively. Classification with moving direction was not adopted for the 24 hour forecast until May 2004. Hatched area means the number of sample is smaller than 20, and the distance of 70% cumulative ratio is not listed.

24 hour forecast

moving direction	moving speed	≦ 5kt	5 <V ≦ 10kt	10 <V ≦ 15kt	15 <V ≦ 20kt	20 <V ≦ 30kt	30kt <V	all moving speed
180°-320°	1996–99 rad.							
	2001–03 70%	**85**	**85**	**78**	**99**			**82**
	No. sample	*85*	*296*	*181*	*36*	*2*	*0*	*600*
320°-10°	1996–99 rad.							
	2001–03 70%	**98**	**77**	**92**				**87**
	No. sample	*79*	*165*	*76*	*5*	*2*	*0*	*327*
10°-180°	1996–99 rad.							
	2001–03 70%	**99**	**87**	**95**	**103**	**105**		**99**
	No. sample	*66*	*96*	*74*	*52*	*51*	*9*	*348*
all direction	1996–99 rad.	90	100	110	100	110	150	100
	2001–03 70%	**95**	**84**	**85**	**103**	**105**		**90**
	No. sample	*230*	*557*	*331*	*93*	*55*	*9*	*1275*

48 hour forecast

moving direction	moving speed	≦ 5kt	5 <V ≦ 10kt	10 <V ≦ 15kt	15 <V ≦ 20kt	20 <V ≦ 30kt	30kt <V	all moving speed
180°-320°	1996–99 rad.	200	170	160				
	2001–03 70%	**152**	**148**	**141**				**144**
	No. sampl	*88*	*244*	*147* e	*8*	*0*	*0*	*487*
320°-10°	1996–99 rad.	150	140	180				
	2001–03 70%	**149**	**145**	**148**				**148**
	No. sampl	*74*	*140*	*38* e	*4*	*0*	*0*	*256*
10°-180°	1996–99 rad.	220	200	210				
	2001–03 70%	**146**	**201**	**150**	**175**	**161**		**171**
	No. sampl	*45*	*74*	*68* e	*47*	*36*	*4*	*274*
all direction	1996–99 rad.	180	170	180	220	240	250	180
	2001–03 70%	**150**	**154**	**144**	**171**	**161**		**151**
	No. sample	*207*	*458*	*253*	*59*	*36*	*4*	*1017*

72 hour forecast

moving direction	moving speed	≦ 5kt	5 <V ≦ 10kt	10 <V ≦ 15kt	15 <V ≦ 20kt	20 <V ≦ 30kt	30kt <V	all moving speed
180°-320°	1996–99 rad.	250	240	220				
	2001–03 70%	**242**	**214**	**220**				**222**
	No. sampl	*81*	*183*	*113* e	*8*	*1*	*0*	*386*
320°-10°	1996–99 rad.	240	240	200				
	2001–03 70%	**257**	**205**	**200**				**219**
	No. sampl	*51*	*111*	*29* e	*1*	*0*	*0*	*192*
10°-180°	1996–99 rad.	350	260	300				
	2001–03 70%	**240**	**285**	**290**	**266**	**228**		**285**
	No. sampl	*26*	*71*	*63* e	*32*	*22*	*1*	*215*
all direction	1996–99 rad.	290	250	250	325	350	500	260
	2001–03 70%	**244**	**222**	**241**	**265**	**228**		**232**
	No. sample	*158*	*365*	*205*	*41*	*23*	*1*	*793*

Verification of the guidance during the period of Typhoon Songda (0418)

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Abstract

As one of the operational meteorological analysis and forecast products, guidance for maximum sustained wind speed (hereinafter referred to as "maximum wind speed") and maximum precipitation has been used to assist forecasters of the Japan Meteorological Agency (JMA) in issuing weather forecasts, warnings and advisories. In this report, practical effectiveness of the guidance for the extreme event was verified, taking an example of the case of Typhoon Songda (0418) which caused considerable damage in Japan. The verification revealed that those guidances were reliable products in a practical level even in this extreme event.

1. Introduction

Japan is a country prone to various kinds of natural disasters, among which tropical cyclone is one of the most devastating events. Since Japan is located in the northwestern edge of the Pacific Ocean, some of the tropical cyclones formed in the tropical or subtropical area go northward and pass through Japan and bring serious natural disasters. Statistically, two or three tropical cyclones make landfall on main islands of Japan in a year, while ten tropical cyclones did in 2004, which hit a new record number of landing tropical cyclones in a year since 1951. Especially, in September 2004, Typhoon Songda (0418) brought extensive damage to Japan mainly due to its strong wind and heavy precipitation.

Tropical cyclone-induced strong wind and heavy precipitation could be extremely hazardous and cause substantial damage. In order to mitigate damage of natural disaster, guidances for strong wind and heavy precipitation were developed by JMA and have been operationally referred to by forecasters to assist them in issuing warnings and advisories to the public in the most timely and appropriate manner.

In this report, an outline of Typhoon Songda (0418) is introduced in section 2, and methods of guidances for strong wind and heavy precipitation are explained in section 3. Prediction by guidances and its verification in the case of Typhoon Songda are shown in section 4 before the conclusion in section 5.

2. Outline of Typhoon Songda (0418)

The best track of Typhoon Songda (0418) is shown in Figure 1. Typhoon Songda was formed near the Marshall Islands on 28 August 2004 and moved northwestward over the Pacific. After passing through Okinawa Islands, the southern subtropical islands of Japan, it recurved northeastward in the East China Sea and made landfall on Kyushu Island, southern main island of Japan, at 00UTC, 7 September. When it landed, the maximum sustained wind speed near the center of the typhoon was 75knots, and the central pressure was 945hPa. After passing through Kyushu Island, it was accelerated by the subtropical jet stream over the Sea of Japan, and then it was transformed into extratropical cyclone over the sea west of Hokkaido, northern main island of Japan, at 00UTC, 8 September.

Wind gust over 50m/s was observed extensively in Japan, setting new records of peak gust at a number of local observatories of JMA. Total amount of precipitation reached more than 900mm at some areas in Kyushu Island and storm surges were also observed along many coastal areas.

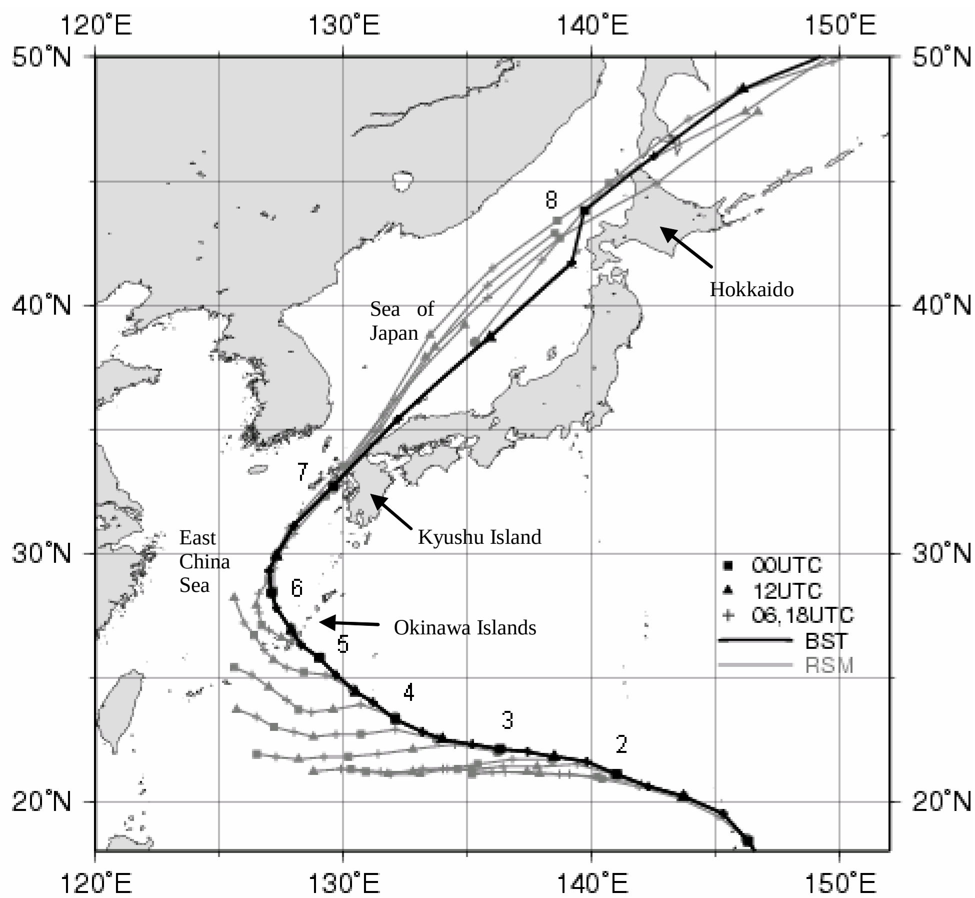

Figure 1 The best track of Typhoon Songda (0418) (black line) and predicted typhoon tracks by RSM at each initial time (gray lines). Six-hourly typhoon positions are plotted. Numbers indicate the dates of September 2004 showing typhoon's positions at 00UTC.

3. Methods of guidance

Guidances for maximum wind speed and maximum precipitation are operationally generated twice a day by JMA, using the output based on the statistical relation between the Regional Spectral Model (RSM) model output and observations. RSM runs twice a day with the initial time of 00 and 12UTC, covering East Asia, and predicts up to 51 hours from the initial time. The details of RSM can be referred to in JMA (2002a). Remarkable advantages of the guidance method are that they can eliminate systematic errors in model output and can represent elements which numerical model cannot predict directly (Wilks, 1995). Specifications of the respective guidances are listed in Table 1.

Table 1 Parameters of guidances

Output	Maximum wind speed and its direction	1-hour and 3-hour maximum precipitation	24-hour maximum precipitation
Initial Time	00, 12 UTC		
Forecast Hour	FT = 03-06, 06-09, …, 48-51		FT = 03-27, 09-33, 15-39, 21-45, 27-51
Input	Regional Spectral Model Output		
Points / Zones	855 AMeDAS* points	362 forecast zones	

*Automated Meteorological Data Acquisition System

A: Maximum wind speed guidance

The maximum wind speed guidance gives maximum value of sustained wind speed and its direction at 3-hour intervals at each observation station. Predictor variables of this guidance are horizontal wind components at 10m above the ground predicted by RSM.

The prediction equations are as follows:

$$U = Um + X1 + X2 * Um + X3 * Vm \qquad V = Vm + X4 + X5 * Um + X6 * Vm$$

where U and V are eastward and northward components of maximum wind speed guidance, respectively. Um and Vm are those of RSM output. X1 through X6 are coefficients which are updated twice a day by Kalman Filtering method. With Kalman Filtering method, the most likely estimation which minimizes the expected root mean square error is obtained. However, the output has a tendency of lower frequency for rare events such as strong wind and heavy precipitation than actually observed data. To correct this bias, the calculated values are rescaled by the "frequency bias correction scheme" (JMA, 2002b).

B: Maximum precipitation guidance

Ebihara (2003) describes the details of the maximum precipitation guidance. There are 362 forecast zones, approximately 1,000km^2 wide each on average, for warnings and advisories issued in Japan. The guidances for maximum precipitation for 1 hour, 3 hours and 24 hours are calculated for each 362 zone. The guidance is composed of mean precipitation amount and the ratio of maximum/mean precipitation amount. Both are estimated for each zone and valid-time period. Mean precipitation is estimated by Kalman Filtering method. Coefficients of each term in regression model are re-estimated twice a day by the method. Maximum/mean precipitation ratio is estimated by artificial neural network.

Accuracy of maximum/mean precipitation ratio depends on mean precipitation amount. When mean precipitation amount is small, this ratio widely varies according to atmospheric conditions. In the contrary case of large mean precipitation amount such as the case of typhoons, the ratio usually converges into a single value. Therefore, maximum precipitation amount is linearly dependent on mean precipitation amount. In this case, accurate estimation of mean precipitation will lead to accurate estimation of maximum precipitation.

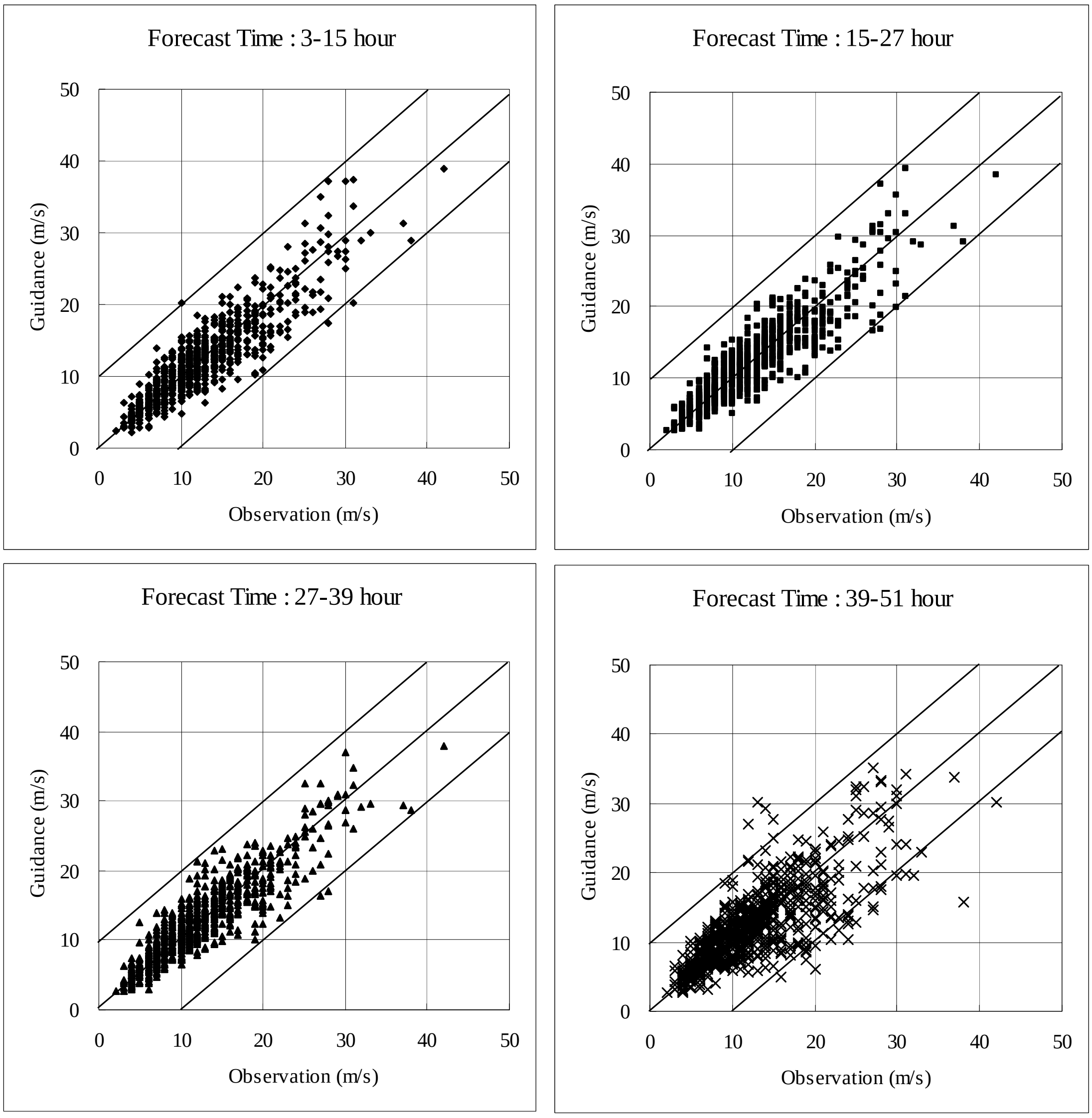

Figure 2 Scatter diagram of the maximum wind speed of the observation and that of guidance. Upper left is for FT=03-15, upper right is for FT=15-27, lower left is for FT=27-39, and lower right is for FT=39-51.

4. Prediction of strong wind and heavy precipitation by guidance and its verification in the case of Typhoon Songda (0418)

Figure 1 shows the best track of Typhoon Songda (0418) and predicted tracks by RSM. RSM predicted with an apparent westward error before the recurvature, followed by fairly good predictions during and after the recurvature.

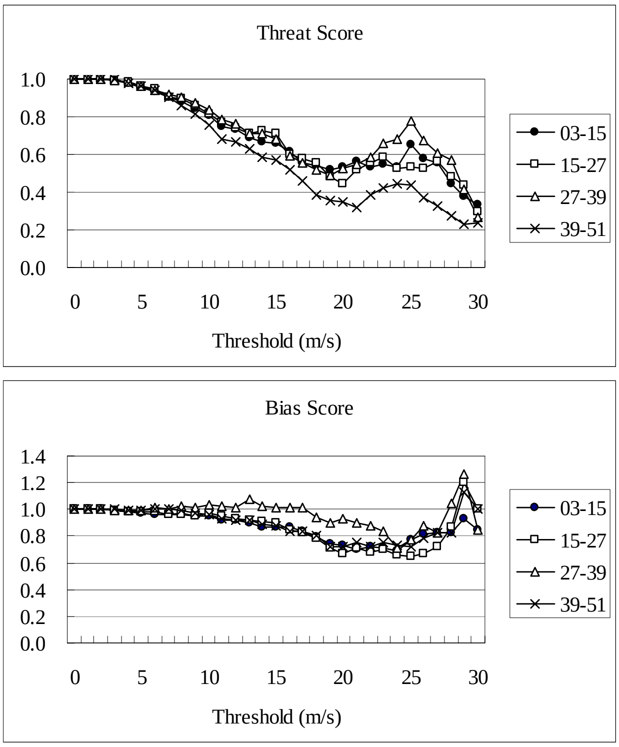

Figure 3　Threat score (upper) and bias score (lower) of the maximum wind speed guidance. Horizontal axis shows threshold wind speed.

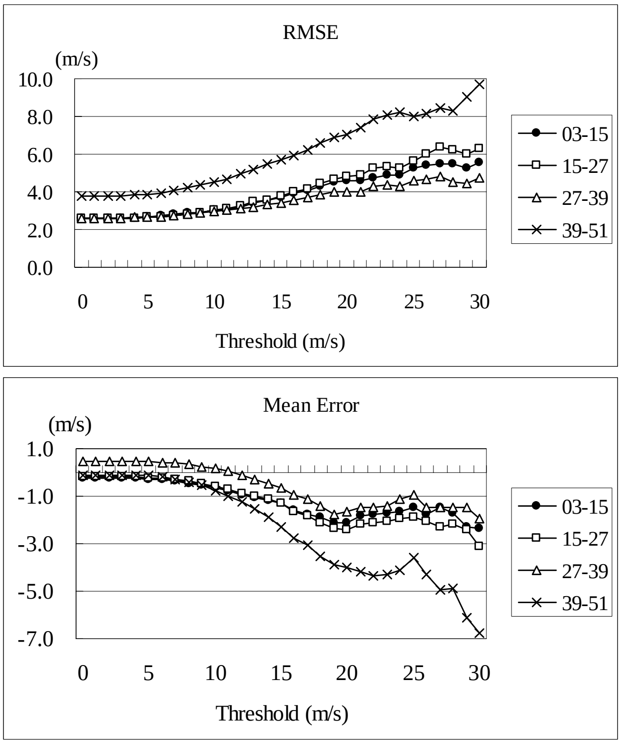

Figure 4　Root mean square error (upper) and mean error (lower) of the guidance.　Horizontal axis shows threshold wind speed.

A: Maximum wind speed guidance

The maximum wind speed guidance during the period of Typhoon Songda was verified.

The observed maximum wind speeds from 4 to 8 September 2004 were compared with those by the guidance at each corresponding period. The maximum wind speed recorded during this period is assumed to be caused by Typhoon Songda at every observation point, because Songda moved along the Japanese Archipelago. The averaged time difference between observed time and predicted time by the guidance is no more than 6 hours.

Figure 2 shows scatter diagrams of the observed maximum wind speeds and those by the guidance for various forecast time ranges. The error of the guidance becomes clearly larger as the forecast time becomes longer. However, it should be noted that most of the absolute errors remain within 10m/s and no systematic bias is found in the figure.

Threat score and bias score of each threshold wind speed are shown in Figure 3. Horizontal axis indicates threshold wind speed. Threshold wind speed means that the score is calculated for the cases in which observed wind speed is more than the threshold value. Threat score of maximum wind speed guidance is 0.5 or more even if threshold wind speed is 20m/s except for 39-51 hours forecast. Bias score of the guidance where threshold wind speed is 20m/s is about 0.7 except for 27-39 hours forecast. The bias score less than 1.0 means that the frequency of the strong wind predicted by the guidance is less than actually observed.

Figure 4 shows root mean square error (RMSE) and mean error (ME) of the guidance. RMSE is about 5m/s for the threshold wind speed of 20m/s except for 39-51 hours forecast. The number of cases in which observed wind speed is more than 20m/s is about 100. RMSE increases as the threshold wind speed increases, however, the increase of RMSE is small except for 39-51 hours forecast. ME is about -2m/s for the threshold wind speed of 20m/s except for 39-51 hours forecast.

One of the reasons the wind speed prediction of the guidance was satisfactory was that the track of Typhoon Songda was fairly well predicted by RSM after the recurvature as shown in Figure 1.

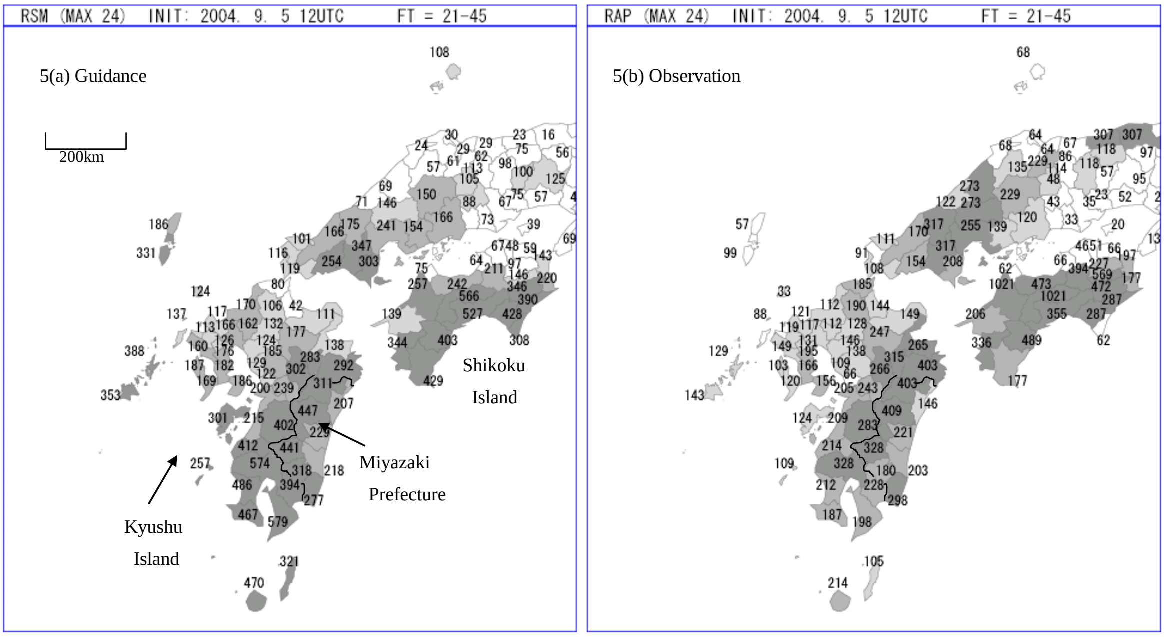

Figure 5 Spatial distribution of 24 hours maximum precipitation (unit: mm/24 hours) in each zone from 09 UTC, 6 September to 09UTC, 7 September in western Japan: (a) maximum precipitation guidance (initial time: 12UTC, 5 September) and (b) Radar-AMeDAS precipitation (analyzed precipitation using radars and raingauges).

B: Maximum precipitation guidance

In this report, discussion is focused on the maximum precipitation guidance for 24 hours as it characterizes the typhoon precipitation.

Figure 5(a) shows an example of maximum precipitation guidance in the western part of Japan. Its initial time is 12UTC, 5 September and forecast time is 21-45 hours. Predicted track of the typhoon by RSM is fairly good at this initial time (Figure 1).

Extremely heavy precipitation more than 400mm/24hours is predicted in some forecast zones, especially in the southern part of Kyushu and Shikoku Islands, where the south-easterly wind around the north eastern part of the typhoon hits directly on mountains. In these areas, heavy rain warning is issued when precipitation more than 200-300mm/24hours (threshold varies with the zone) is predicted. This guidance was available at 16UTC, 5 September well before the landfall of Typhoon Songda on Kyushu Island, which means that these warnings can be issued well in advance with sufficient lead time.

In Miyazaki Prefecture, southeastern part of Kyushu Island, relatively small amount of precipitation slightly more than 200mm/24hours is predicted in the coastal zones, while much more precipitation is predicted along the mountains. It is found that maximum precipitation guidance can express such difference reflecting local topography. Figure 5(b) shows Radar-AMeDAS analyzed precipitation derived from the radar and raingauges observations in the same period as Figure 5(a). Observed precipitation also has local topographical distribution and it corresponds well to the predicted guidance. Scatter diagram between guidance and observed precipitation is shown in Figure 6. There is a close correlation between the guidance and observation, although guidance for a few forecast zones is far underestimated. This guidance is found to be a very useful product to assist the forecasters in issuing typhoon information.

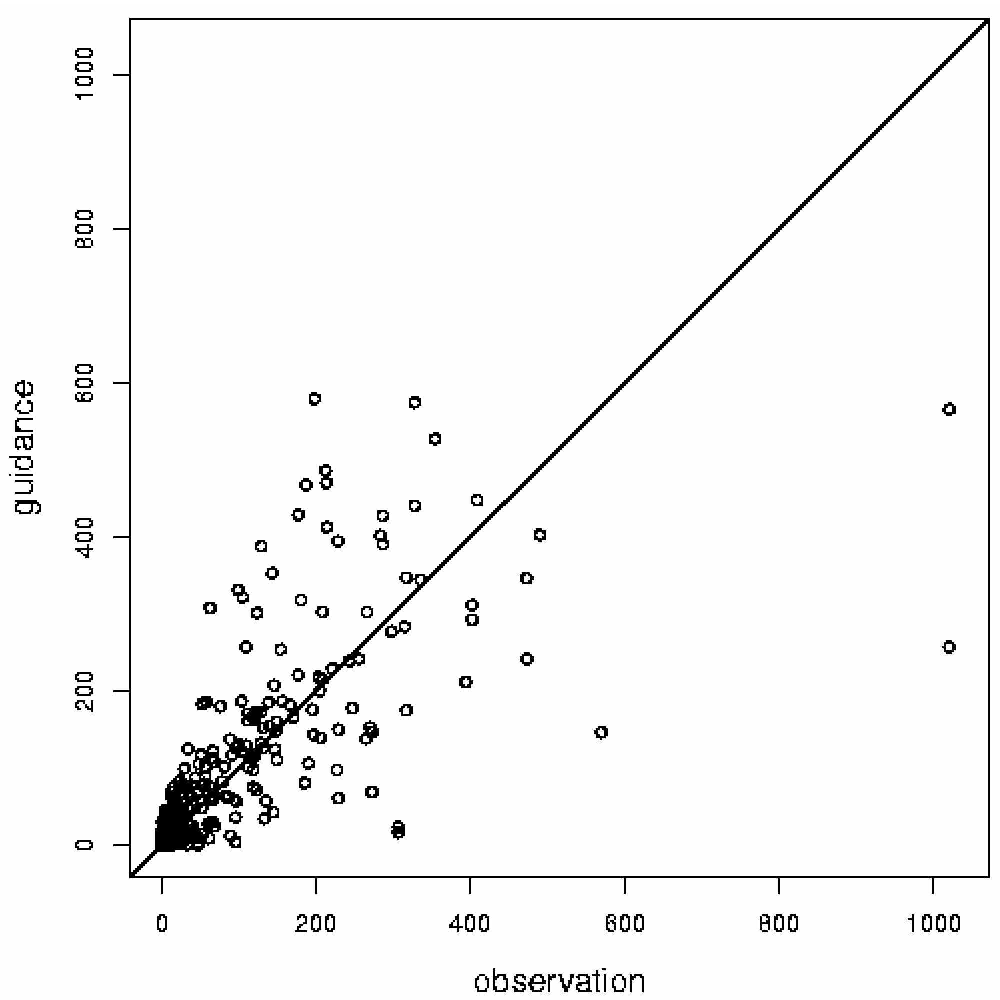

Figure 6 Scatter diagram of 24 hours maximum precipitation of guidance and observation (unit: mm/24hours). Initial time and valid time are same as Figure 5. One circle corresponds to one forecast zone and all 362 zones in Japan are plotted.

5. Conclusion

Guidance for maximum wind speed and maximum precipitation was verified during the period of Typhoon Songda (0418).

For the threshold wind speed of more than 20m/s, threat score and bias score of maximum wind speed were mostly about 0.5 and 0.7, and RMSE and ME were mostly about 5m/s and -2m/s, respectively.

Guidance for maximum precipitation represents very heavy rainfalls with the precipitation more than 400mm/24hours. Although observed precipitation was more than the predicted amount by the guidance at some areas, the guidance illustrates the topographic distribution of precipitation, such as in costal zones and areas along the mountains.

References:

Ebihara, S., 2003: The development of guidance for forecast of maximum precipitation amount, Technical Review, RSMC Tokyo-Typhoon Center, 6, 1-17.

Japan Meteorological Agency, 2002a: Regional Spectral Model (JMA-RSM0103), Outline of the operational numerical weather prediction at the Japan Meteorological Agency, 64-81.

Japan Meteorological Agency, 2002b: Guidance for Short-range Forecasting, Outline of the operational numerical weather prediction at the Japan Meteorological Agency, 111-118.

Wilks, D. S., 1995: Statistical methods in the atmospheric sciences: an introduction, Academic Press, 199-210.